Spatial Autocorrelation for Malaria Hotspots Identification in Mekong Basin, Ubon Ratchathani, Thailand

Jaruwan Wongbutdee MSc*,
Wacharapong Saengnill MSc*

** College of Medicine and Public Health, Ubon Ratchathani University, Ubon Ratchathani, Thailand*

Background: *Malaria is a major public health problem in Thailand transmitted by the Anopheles mosquito. Spatial autocorrelation effectively measures epidemiology, distribution of diseases, and is important in the understanding of the distribution of malaria spatial patterns.*

Objective: *This study aimed to detect malaria hotspots in the Mekong basin in Ubon Ratchathani using spatial statistical analyses between 2011 and 2014.*

Material and Method: *Data of malaria cases and incidence rates were collected during years 2011 to 2014. The study area had 42, 130, 175, and 119 cases in 2011, 2012, 2013, and 2014, respectively. Moran's I was used to calculate the correlation of spatial autocorrelation. Getis-Ord Gi* identified the differentials of the patterns of hotspots.*

Results: *The incidence rates showed 59.38, 183.23, 253.31, and 160.27 per 10,000 population in years 2011, 2012, 2013, and 2014, respectively. The results in 2012, 2013, and 2014 were 0.347, 0.606, and 0.393, respectively of Moran's I value. Therefore, the Z-score statistics for these years showed cluster patterns of strong significance (p-value <0.01) while 2011 had random patterns. The Getis-Ord General G* statistics showed that 2013 had the highest number of hotspots, followed by 2012 and 2014.*

Conclusion: *Spatial autocorrelation can estimate unknown located spatial data from the values of located attributed data with reference to the trend and distribution of malaria. Therefore, the information can support and confirm incidences and outbreaks of malaria cases. Spatial autocorrelation is utilized for decision-making in the support of plans, epidemiological control, and surveillance of malaria.*

Keywords: *Malaria incidence, Spatial autocorrelation, Hotspots*

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The *Anopheles* mosquito carries the malaria disease and is found in many tropical regions and community areas(1). Malaria is a major public health problem in Thailand and factors that affect its distribution and outbreak include rainfall, temperature, forests, humidity, and manufactured containers(2). People obtain the malaria parasite from bites by infected *Anopheles* mosquitoes(3) with bite times ranging between dusk and dawn.

Malaria prevention and control target intervention and the promotion of knowledge and behavior of people in areas such as standing, stagnant water, sleeping under mosquito nets, and wearing sensible clothes. Despite these efforts, there are continuous outbreaks. Many studies have used Geographic Information System (GIS) to analyze and represent spatial data to create databases of malaria and risk areas(4,5) for planning, control, and surveillance, and it is used effectively to measure epidemiology and distribution of diseases(6,7). Many studies integrate data of attributes and space to analyze temporal spatial patterns of malaria disease. Spatial autocorrelation calculates relationships between two objects, and is used to measure simultaneously relationship between locates and values of attributes. Zhou (2005)(8) used spatial autocorrelation to investigate the distribution of malaria on a large scale in Thailand. Thus, researchers use spatial autocorrelation to simulate spatial malaria patterns as clustered, random, and/or dispersed. Generally, Moran's I and Getis-Ord Gi* statistics are applied to identify high and low malaria incidences in investigated areas. In addition, spatial statistics are a tool to describe and analyze data to accept or reject

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Correspondence to:
Saengnill W, College of Medicine and Public Health, Ubon Ratchathani University, Ubon Ratchathani 34190, Thailand.
Phone: +66-45-353900
E-mail: mdwatcsa@ubu.ac.th

null hypotheses.

This study aimed to detect malaria hotspots in the Mekong basin in Ubon Ratchathani between 2011 and 2014 by the use of spatial statistical analyses.

Material and Method

Study area

The Mekong River is located in the eastern region of Thailand and forms the border with Lao PDR. Ubon Ratchathani is a province in the Mekong basin and was selected as the study area. Five districts in the province, Khemarat, Khong Chiam, Sri Muang Mai, Phosai, and Sirinthorn are part of the basin; these five are made up of thirty sub-districts (Fig. 1). The study area covers 2,797.15 km^2 and has a population of 239,345. The main occupation is agriculture concentration in growing of rice, rubber, and cassava.

Data collection

Data about malaria cases were collected for the years 2011 to 2014 from Ubon Ratchathani Provincial Health Office. The study area had 26, 126, 155, and 103 cases in 2011, 2012, 2013, and 2014, respectively. Descriptive studies of epidemiology regularly use incidences of diseases as means of measurement. The incidence of a disease is the number of new cases that occur in a population at risk of malaria during a period of time. The malaria incidence was recorded per 10,000 population in the sub-districts (Fig. 2). Morbidity rates in 2013 were the highest (253.31 cases per 10,000 population) and 2011 presented the lowest (59.38 cases per 10,000 population). Malaria cases and morbidity rates were connected with ageographic map at the sub-district level. Thirty sub-district boundaries were geo-referenced in the Universal Transverse Mercator projection zone 48N on World Geodetic System 1984 ellipsoid. Fig. 3 shows the morbidity rates in the Mekong basin, Ubon Ratchathani.

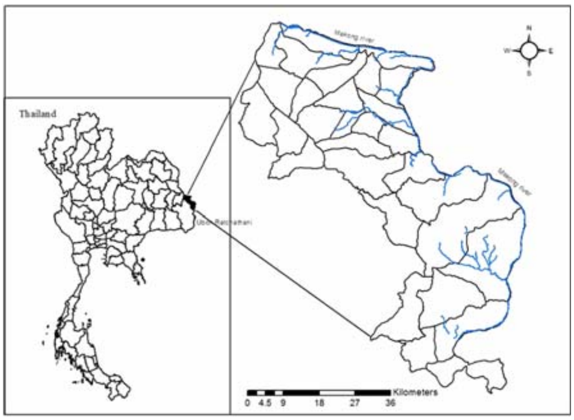

Fig. 1 Thirty sub-districts in the Mekong basin, Ubon Ratchathani, Thailand.

Spatial autocorrelation

Spatial autocorrelation is correlation of two near objects or more related than that of distant objects. This tool measures simultaneously the relationships between locates and values of attributes. The output patterns show clustered, dispersed, or random. Normally, Moran's I is used to calculate correlations of spatial autocorrelation particularly variables of the

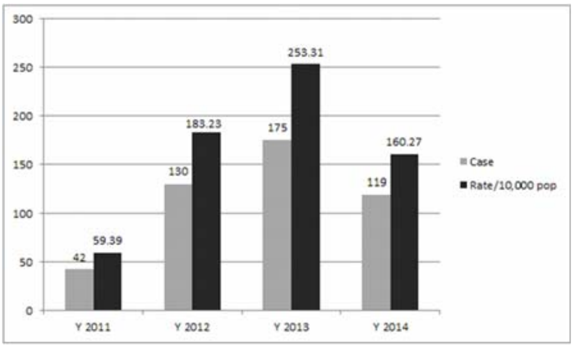

Fig. 2 Malaria cases and morbidity rates from 2011 to 2014.

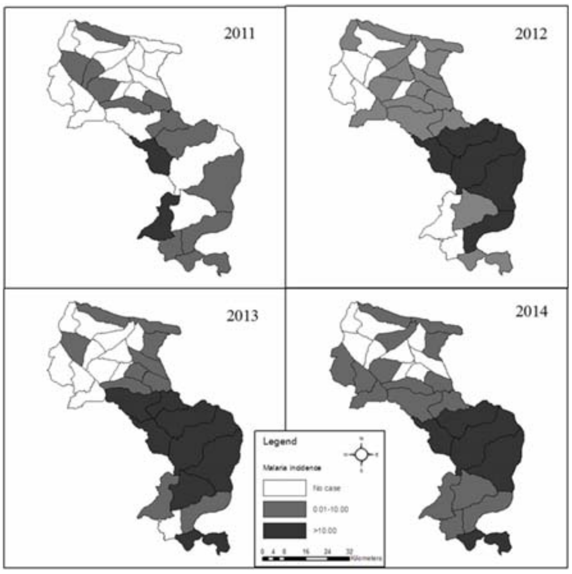

Fig. 3 Geographic maps of morbidity rates between 2011 and 2014 show polygons of the thirty sub-districts. The black color represents a high incidence and white represents no cases.

intervals and ratio scales. The Moran's I statistic is given as:

$$I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} \sum_{i=1}^{n} (x_i - \bar{x})^2} \quad (1)$$

where X_i is a value of malaria mobility variable for feature i, $W_{i,j}$ is the spatial weight between feature *i* and *j*, and n is equal to the total number of features(9). The value of Moran's I index ranges from -1 to 1. The negative spatial autocorrelation means a dispersed pattern, while positive value implies a strong clustered pattern. A random pattern is defined by value "0"(10). The Z-score statistic calculates assumptions of a null hypothesis to assess significance.

However, Moran's I cannot identify the differences of high and low patterns of the feature but only shows the patterns of spatial autocorrelation. This study chose the Getis-Ord Gi* effective statistic tool for spatial autocorrelation similar to Moran's I but it presented each feature of patterns of high spot, low spot, or normal spot values in the study area. The Z-score statistic calculates assumptions of null hypothesis to assess significance(11). If there are statistically significant more positive Z-scores than the Z-score (Z-score <-1.96, or Z-score >1.96), the null hypothesis is rejected, meaning the acceptance of clustering of high value (hotspot). The Getis-Ord Gi* statistic is given as:

$$G_i^* = \frac{\sum_{j=1}^{n} \omega_{ij} x_j - \bar{X} \sum_{j=1}^{n} \omega_{ij}}{S \sqrt{\frac{n \sum_{j=1}^{n} \omega_{ij}^2 - \left(\sum_{j=1}^{n} \omega_{ij}\right)^2}{n-1}}} \quad (2)$$

where X_i is a value of malaria mobility variables for feature i, $W_{i,j}$ is the spatial weight between feature *i* and *j*, n is equal to the total number of features, and:

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - \bar{x}^2} \quad (3)$$

Ethical clearance

This study was approved by the Office of Ubon Ratchathani University Research Ethics Committee on February 4, 2015 (Document number: UBU-REC-21/57).

Results

Results outlined the malaria cases and morbidity rates between 2011 and 2014 in the Mekong basin, Ubon Ratchathani. The morbidity rate of malaria was the highest in 2013 at 253.31 per 10,000 population, about 183.23 in 2012, and around 160.27 in 2014. Overall observations indicated that malaria cases and morbidity rates increased from 2011 to 2013 and slightly decreased in 2014 (Fig. 2).

Fig. 3 shows geographic map of the morbidity rates between 2011 and 2014 indicating high rates in the lower Mekong basin between years 2012 and 2014, and low rates in the upper areas.

Moran's I statistics was used to measure spatial autocorrelation patterns. The results in 2012, 2013, and 2014 had 0.347, 0.606 and 0.393 of the values of Moran's I. Therefore, the Z-score statistics showed cluster patterns and were strongly significant (*p*-value <0.01) while 2011 had random patterns (Table 1). Getis-Ord General G* statistics measured malaria hotspots and results showed that 2013 had the highest hotspot, followed by 2012 and 2014 (Fig. 4).

Discussion

Malaria is a social and economic problem to the development of countries. It is transmitted by bites of female *Anopheles* mosquitoes(1) and results in acute febrile illness presenting symptoms of fever, headache, chills, and vomiting. Malaria is caused by any of four parasites, *Plasmodium falciparum, P. vivax, P. ovale,* and *P. malariae*(12,13).

The Mekong basin in Ubon Ratchathani

Table 1. Moran's I spatial autocorrelation statistics related to malaria incidence

Moran's I	2011	2012	2013	2014
Moran's index	0.066	0.347	0.606	0.393
Variance	0.016	0.008	0.017	0.007
Z-score	0.788	4.053	4.827	4.875
The *p*-value	0.430	<0.010*	<0.010*	<0.010*
Pattern	Random	Clustered	Clustered	Clustered

*The *p*-value <0.05

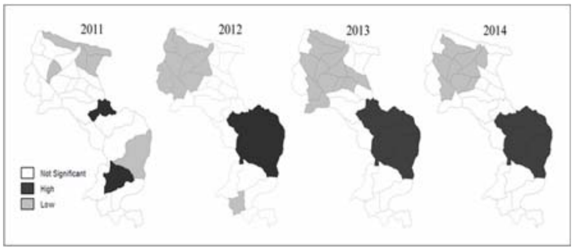

Fig. 4 Getis-Ord General G* spatial auto correlation statistics show malaria hotspots. The black color represents statistically significant positive Z-scores of hotspots between 2011 and 2014.

Province is a mountainous area with people engaged in agricultural activities in rice paddy fields, rubber and cassava plantations, and forests, ideal habitats for mosquitoes and the distribution of malaria.

From 2011 to 2014, malaria incidences were high (Table 1). Interviews of volunteers and staff in Nam Thaeng Health Promotion Hospital found that people had high levels of preventive perception of malaria but low levels of preventive behavior. It appeared that people received information about malaria mainly via campaigns, promotions, and community broadcast towers. However, incidence rates and new cases of malaria were reported and distributed over all areas. Risky behavior involved not sleeping under nets at night, having containers, such as used tires and plant pots, full of water around households as potential breeding sites, and wearing inappropriate clothes in agricultural areas.

Spatial autocorrelation by Moran's I statistics showed the pattern clusters between 2012 and 2014. This monitoring of malaria is valid as the areas are homogeneous and similar value clusters affect the malaria outbreaks and is an effective technique to identify risk areas(14). The Getis-Ord Gi* statistic is a similar tool to Moran's I but it analyze spatial autocorrelation of malaria hotspots clusters(15,16). Results showed hotspot areas in the lower Mekong basin. These areas are mainly forested, such as Pha Tam National Park Kaeng Tana National Park, and Phu Lon Wildlife Reserve. Environmental and meteorological factors, such as streams, rainfall, temperatures, and humidity, influenced the habitats of mosquitoes(17). Spatial autocorrelation estimates of unknown locate spatial data from values of located attribute data represents trends and distributions of malaria. Therefore, this information confirms incidences and outbreaks of malaria. Spatial autocorrelation can be utilized for planning, control, and surveillance of malaria disease.

What is already known about this topic?

Malaria is a major a problem in tropical regions. Several studies presented an epidemiology of malaria through morbidity and mortality and advanced statistics tests. Geographic Information System (GIS) is a good tool for monitoring, planning, and control of malaria.

What this study adds?

Few studies exist about the use of spatial autocorrelation in relation to malaria in Thailand. As a result, this study used Moran's I and Getis-Ord Gi* statistics to analyze spatial autocorrelation of hotspot clusters. It integrated data between spatial and attribution to relationships via co-ordinated reference systems in the real world. Results showed that hotspot clusters can be confirmed by the data distribution of malaria and is able to provide support for surveillance and control.

Acknowledgements

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Potential conflicts of interest

None.

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การใช้สหสัมพันธ์เชิงพื้นที่เพื่อจำแนกจุดร้อนแรงของโรฃมาลาเรียในลุ่มน้ำโขงจังหวัดอุบลราชธานี ประเทศไทย

จารุวรรณ์ วงบุตดี,วัชรพงษ์ แสงนิล

ภูมิหลัง: *มาลาเรียเป็นปัญหาที่สำคัญของสาธารณสุขในประเทศไทย มียุงก้นปล้องเป็นพาหะนำโรค การใช้สถิติสหสัมพันธ์เชิงพื้นที่เป็นเครื่องมือที่มีประสิทธิผลในการวัดการระบาดและการกระจายของโรคมาลาเรีย มีความสำคัญที่ทำให้เข้าใจรูปแบบการกระจายโรคมาลาเรีย*

วัตถุประสงค์: *เพื่อตรวจสอบจุดร้อนแรงของโรคมาลาเรีย โดยใช้สถิติสหสัมพันธ์เชิงพื้นที่ระหว่างปี 2554-2557*

วัสดุและวิธีการ: *รวบรวมข้อมูลผู้ป่วยโรคมาลาเรียและอัตราป่วย 4 ปี (พ.ศ. 2554-2557) ซึ่งมีจำนวนผู้ป่วยปี พ.ศ. 2554 จำนวน 26 ราย พ.ศ. 2555 จำนวน 126 ราย พ.ศ. 2556 จำนวน 155 ราย และ พ.ศ. 2557 จำนวน 103 ราย วิเคราะห์ข้อมูลสหสัมพันธ์เชิงพื้นที่โดยใช้สถิติ Moran's I และใช้ Getis-Ord Gi* วิเคราะห์จุดร้อนแรงเชิงพื้นที่ของโรคมาลาเรีย*

ผลการศึกษา: *พบว่า พ.ศ. 2554 มีอัตราป่วยโรคมาลาเรีย 59.39 ต่อประชากรหมื่นคน พ.ศ. 2555 อัตราป่วย 183.23 ต่อประชากรหมื่นคน พ.ศ. 2556 อัตราป่วย 253.31 ต่อประชากรหมื่นคน และ พ.ศ. 2557 อัตราป่วย 160.27 ต่อประชากรหมื่นคนจากการทดสอบ Moran's I พบว่าปี พ.ศ. 2555-2557 มีรูปแบบเชิงพื้นที่แบบกลุ่มมีค่า Moran's I เท่ากับ 0.281, 0.626 และ 0.281 ตามลำดับ สำหรับการทดสอบ Getis-Ord Gi* พบมีจุดร้อนแรงในปี พ.ศ. 2556 มากที่สุดตามด้วย พ.ศ. 2555 และ พ.ศ. 2557*

สรุป: *สหสัมพันธ์เชิงพื้นที่จะประมาณค่าของตำแหน่งที่ไม่ทราบจากข้อมูลที่มี ซึ่งสามารถแสดงแนวโน้มการกระจายของโรคมาลาเรีย ดังนั้นข้อมูลที่ได้สามารถที่สนับสนุนและยืนยันอัตราป่วยและจำนวนผู้ป่วยของการระบาดมาลาเรียได้ และมีประโยชน์ต่อการสนับสนุนการวางแผน การเฝ้าระวังและควบคุมโรคมาลาเรียได้*